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OSCILLATIONS OF THE ICE COVER EXCITED BY INTERNAL WAVES OF THE --ETC(U)
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(Kolebaniya ledyanogo pokrova, obuslovlennyye vnutrennimi volnami Ledovitogo Okeana)

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## OSCILLATIONS OF THE ICE COVER EXCITED BY INTERNAL WAVES OF THE ARCTIC OCEAN

[Smirnov, V.N., Kolebaniya ledyanogo pokrova, obuslovlennyye vnutrennimi volnami Ledovitogo Okeana, AN SSSR, Doklady, Vol. 206, No. 5, 1972, pp. 1106-1108, Russian]

In 1970 tiltmeters installed on Drift Station North Pole 20 [1106
recorded oscillations of the ice cover with periods of up to 25 minutes. Preliminary results of the investigation indicate that these oscillations are excited by internal waves generated in the highly stratified waters of the Arctic ocean basin.

The pack ice was approximately 3.0 by 5.0 km across and was about 5 m thick. Vertical oscillations of the ice pack were recorded by tiltmeters, horizontal pendulums recording tilting of the ice surface. The pendulum displacement was converted into electric current and recorded on a moving strip of photographic paper. Four identical tiltmeters were installed on the ice cover. Two of the instruments were installed at the same point, at right angles to each other. The remaining tiltmeters were located along a straight line at 25 m intervals. Such arrangement of the instruments made it possible to visually correlate the oscillation phases and to determine the phase velocity and the direction of propagation of the wave. Oscillations from all four sensors were recorded simultaneously by the N-700 light-beam oscillograph. The frequency response of the recording channel is flat in the range of periods observed and the sensitivity to tilts is 0.030 s arc/mm. The double amplitude 2A of vertical displacements of the ice cover was determined from the formula $2A = \lambda\varphi/\pi$, where $\lambda$ is the wave length and $\varphi$ is the maximum tilt of the ice floe during propagation of the wave. Fig. 1 shows typical recordings of oscillations of the ice cover. Relatively short-period wave ($\tau$ = 20 to 25 s), such as are caused by swell, are super-
posed on long-period oscillations. Fig. 2 shows vector diagrams of [1107
polarization of long-period waves in the plane of the ice floe. A histogram of the periods (Fig. 3) was constructed for a half-year cycle of continuous observations. Of the n = 1120 periods determined, approximately 70 percent fall in the range 6 to 13 minutes.

Table 1 gives the values of wave parameters during specified periods of observation: period T, phase velocity c, wave length $\lambda$, double amplitude 2A, and propagation direction $\alpha$. All calculations were made on the assumption that the drift velocity is zero, i.e. the Doppler effect was not taken into account.

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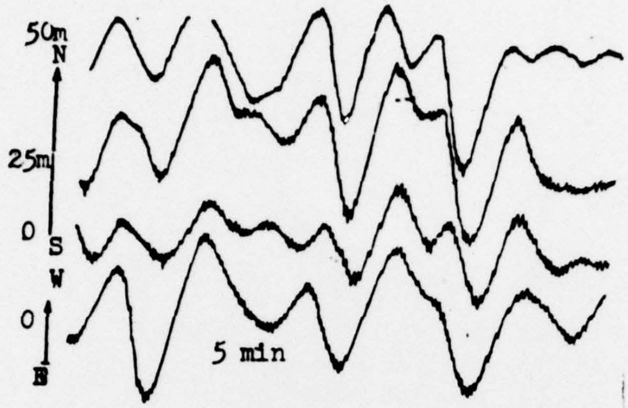


Fig. 1 Typical record of oscillation of the ice cover obtained with the aid of special azimuthal placement of tiltmeters

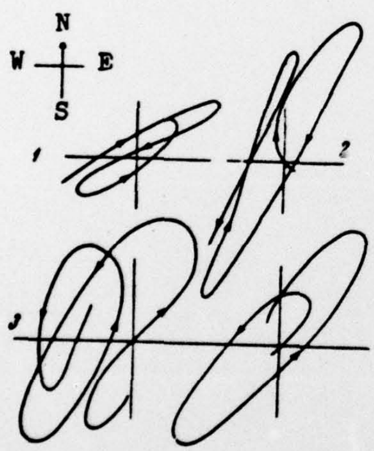


Fig. 2 Wave polarization in the horizontal plane for the following observation periods: 1 - July 11; 2 - August 27; 3 - August 28

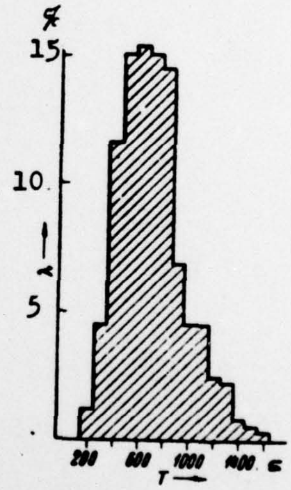


Fig. 3. Histogram of oscillation periods of the ice cover

These are the first recordings of surface gravity waves in ice-covered sea, having phase velocities between 0.5 and 2.0 m/s. The results of theoretical investigations and processing of observational data on flexural gravity waves in the period range between 0.1 and 1000 s are published in references [1 to 4]. It was established that natural oscillations of the ice cover are caused primarily by the breakup of ice, effects of wind, and transmission of gravity waves incident on the ice from the free water side.

| Date | T, s | c m/s | λ, m | α, 0 | 2A, mm |
|---|---|---|---|---|---|
| 11 VII | 840 | 1.6 | 1340 | 57 | 4.00 |
| 27 VIII | 660 | 1.1 | 730 | 26 | 4.36 |
| 28 VIII | 880 | 1.1 | 980 | 41 | 4.90 |
| 28 VIII | 800 | 1.2 | 960 | 36 | 4.33 |
| 28 VIII | 900 | 1.0 | 900 | 180 | 3.12 |
| 28 VIII | 1080 | 0.7 | 760 | 180 | 2.66 |
| 14 IX | 700 | 2.0 | 1400 | 50 | 4.20 |
| 14 IX | 670 | 0.5 | 330 | 303 | 0.84 |
| 14 IX | 670 | 0.6 | 400 | 300 | 1.00 |

The results of our observations appear to indicate that the source responsible for generation of such slow waves is found in the ocean depths. This assumption appears to be substantiated by the fact that the propagation parameters of such types of waves along the ocean surface (Table 1) are in good agreement with the existing concepts of short-period internal waves. It can be assumed that internal waves, which are proper oscillations of the layers of stably-stratified sea, reach the surface causing oscillations of the ice cover with the same period, phase velocity and direction of propagation. The polarization of internal waves (Fig. 2) indicates a sufficiently stable progressive wave with a specific direction of propagation. [1108
This important factor may serve as a definite criterion making it possible to establish the characteristics of wave motion. Thus, oscillations of the ice cover with very low propagation velocities may provide data on the dynamic state of deep water masses.

In conclusion the authors would like to express their gratitude to V.T. Spitsyn for the assistance provided on the drifting station and also to V.P. Gavrilo, V.G. Savchenko and B.Ye. Kheysin for a useful discussion.

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